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Occupational risk assessment in E-waste plant: Progress achieved over years †

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‘**Electrical and electronic equipment**’ or ‘**EEE**’ means equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields and designed for use with a voltage rating not exceeding 1 000 volts for alternating current and 1 500 volts for direct current;

E-waste is the fastest growing waste stream in the EU and less than 40% is recycled.

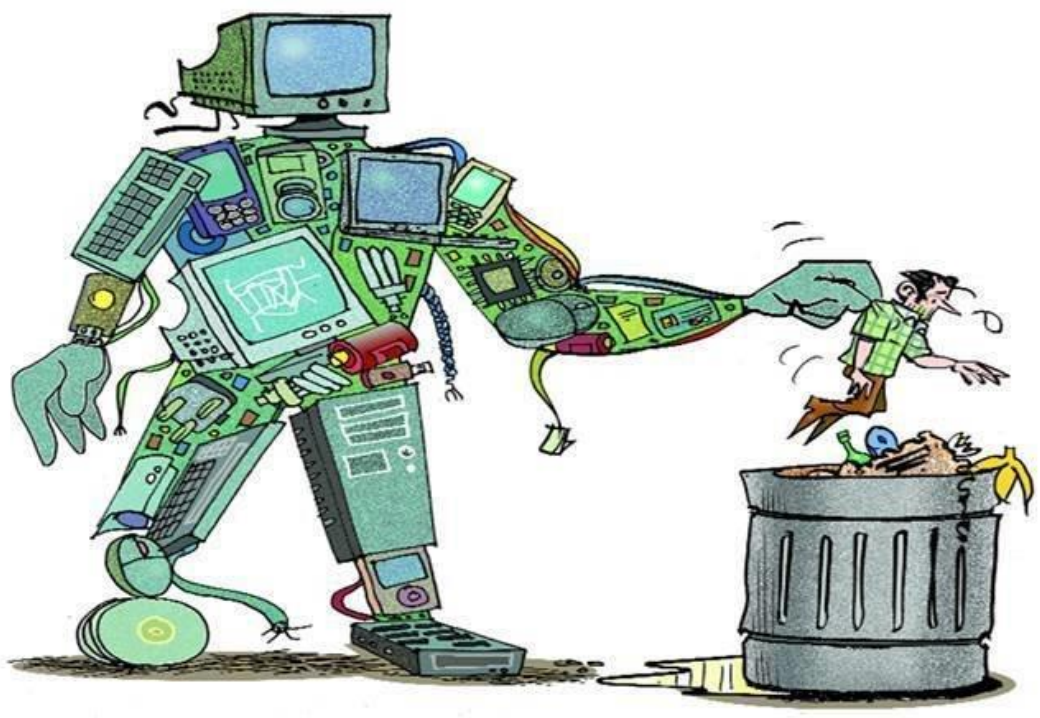
D.Lgs. 49/2014

Directive 2012/19/EU

- ✓ an obligation for producers and distributors to finance a system for the recovery and recycling of products placed on the market (“extended producer responsibility” principle)
- ✓ measures aimed primarily at preventing the production of WEEE and their reuse, recycling and other forms of recovery to reduce the disposed waste volume.

Risks Associated with the End-of-Life Treatment of Electrical and Electronic Equipment

- The major hazards in the recycling chain are associated with the size reduction and separation steps. Shredding, grinding or other size reduction processes lead to generation of dust on which harmful substances can be absorbed



Components	Found in	Substances of concern
Cathode ray tubes	Old TV sets, PC monitors, oscilloscopes	Pb in cone glass Ba in electron gun getter Cd in phosphors
Printed circuit boards	Ubiquitous, from beepers to PCs	Pb, Sb in solder Cd, Be in contacts Hg in switches BFRs in plastics
Plastics	Wire insulation, plastic housing, circuit boards	Polyvinyl chloride (PVC) Brominated flame retardants (BFR) Polychlorinated biphenyl (PCB)

….HUMAN HEALTH RISK??

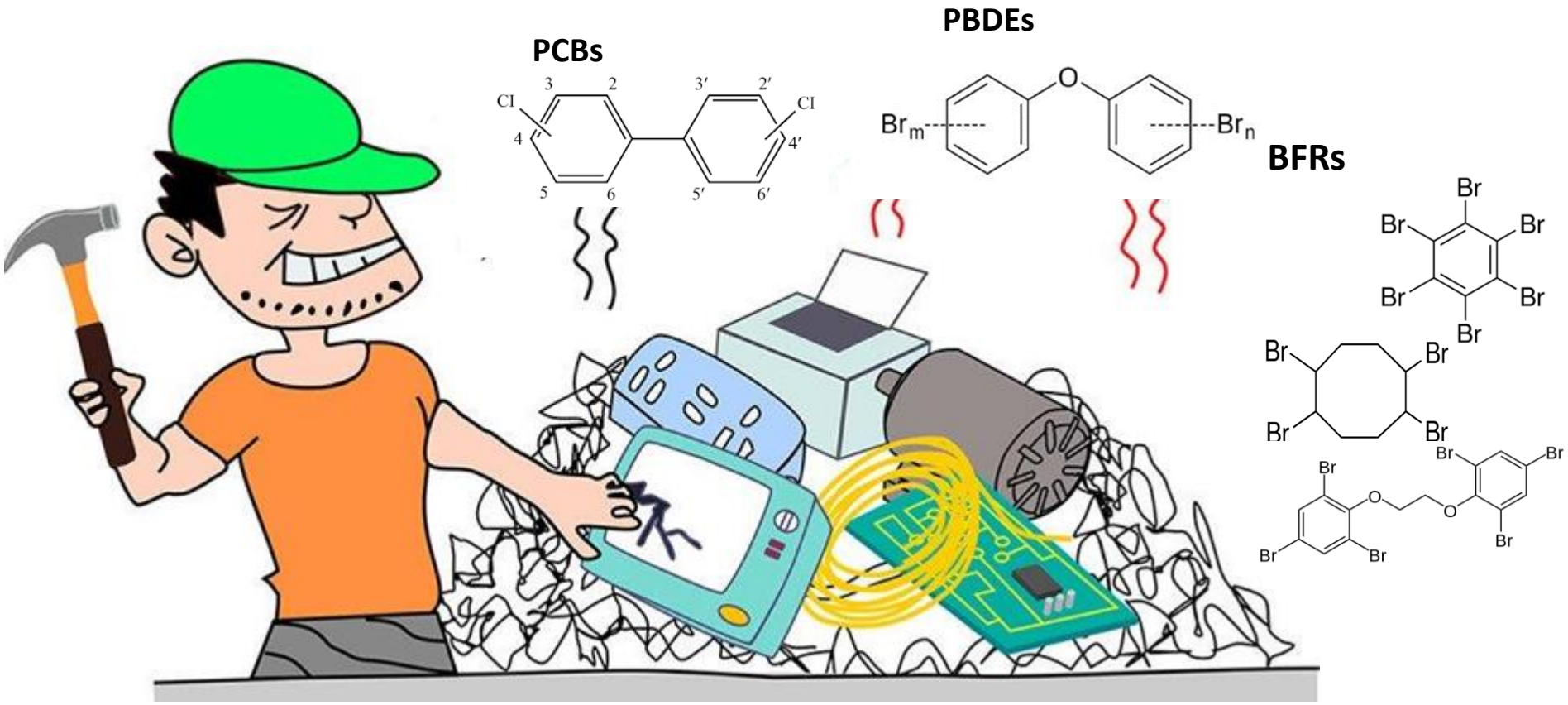
E-waste recycling can lead to direct or indirect exposure to a variety of hazardous substances that are contained in EEE or formed and released by unsafe recycling practices

- *Individuals who directly engage in e-waste recycling with poor protection are exposed to non-negligible risks*

- *Unsafe recycling techniques used to regain valuable materials often increase the risk for hazardous exposures.*

Aim of work

- *Study of Risk Assessment of Workers Exposed to three different classes of compounds in both settled dust and airborne particulate matter (PM) over the years*



Evolution of WEEE plant from 2017 to 2021

Weighing

Discharge

Storage

2017

Disassembling + Shredding

2021

Z1

Shredding

Z2

Disassembling

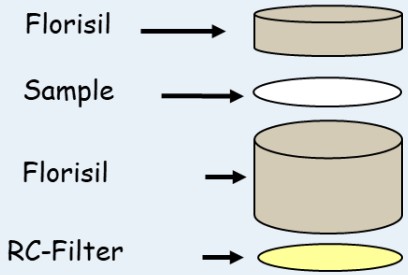
Sample collection

Dust collection

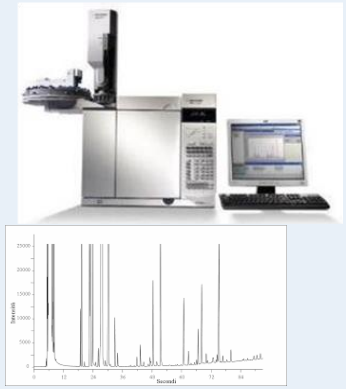
Dust sieved to 63 µm

PM_{10}

→ <u>SKC impactors</u>
37 mm teflon filters

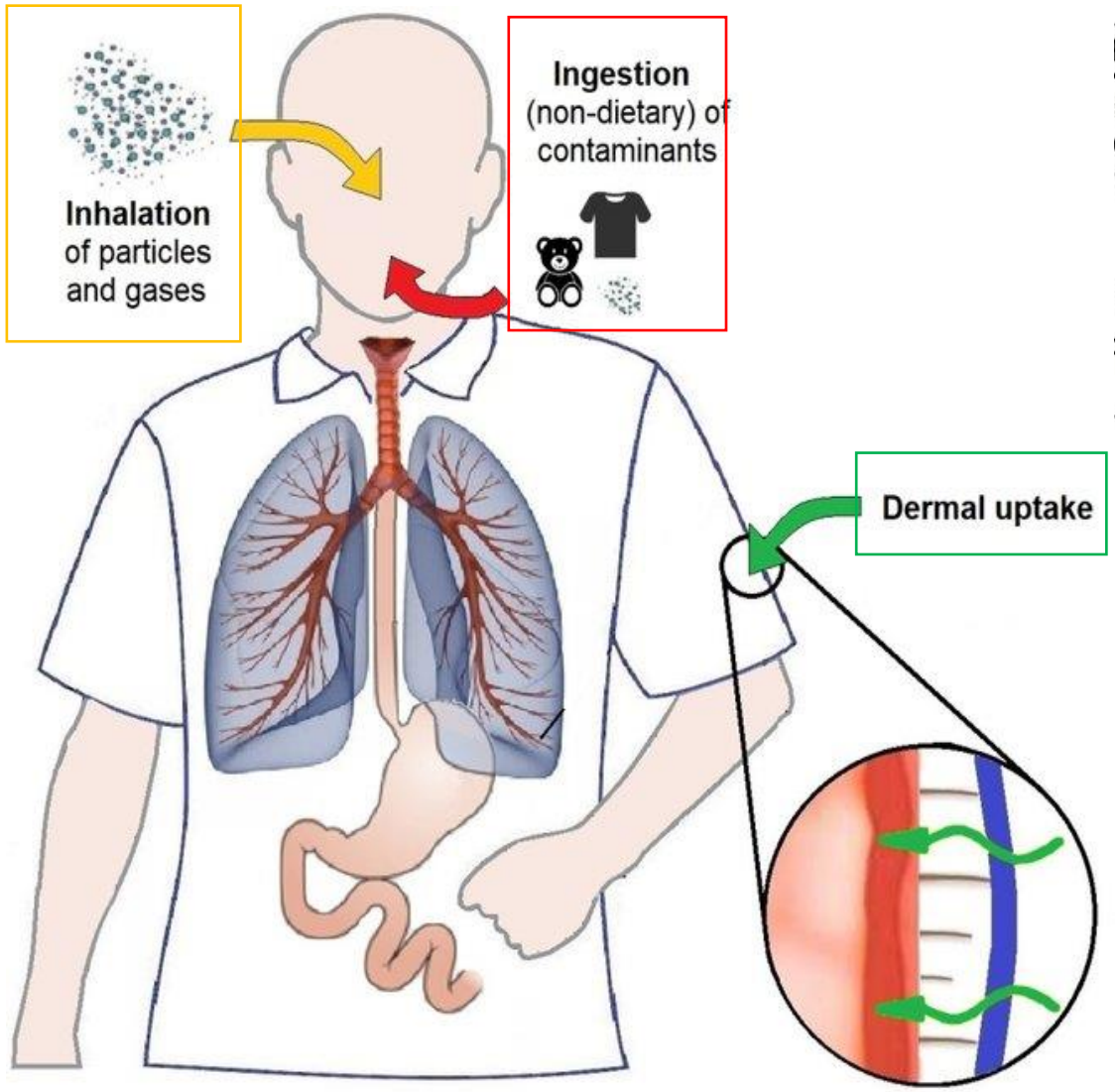


Extraction and purification



HPLC-MS/MS and GC-MS analysis

EXPOSURE PATHWAYS



Inhalation of particles

Accident ingestion of dust

Dermal absorption via particle contact

$$CR_{inhalation} = \frac{Ci \times EF \times ET \times ED}{AT^{*} * 365 * 24} \times IUR$$

$$CR_{ingestion} = \frac{Ci \times IngR \times EF \times ED \times CF}{BW \times AT} \times SFO$$

$$CR_{dermal} = \frac{Ci \times SA \times AF \times ABS \times EF \times ED \times CF}{BW \times AT} \times \frac{SFO}{GIABS}$$

$$HQ_{inhalation} = \left[\frac{Ci \times EF \times ET \times ED}{AT^{*} * 365 * 24 * 1000} \right] / RfC$$

$$HQ_{ingestion} = \left[\frac{Ci \times IngR \times EF \times ED \times CF}{BW \times AT} \right] / RfD$$

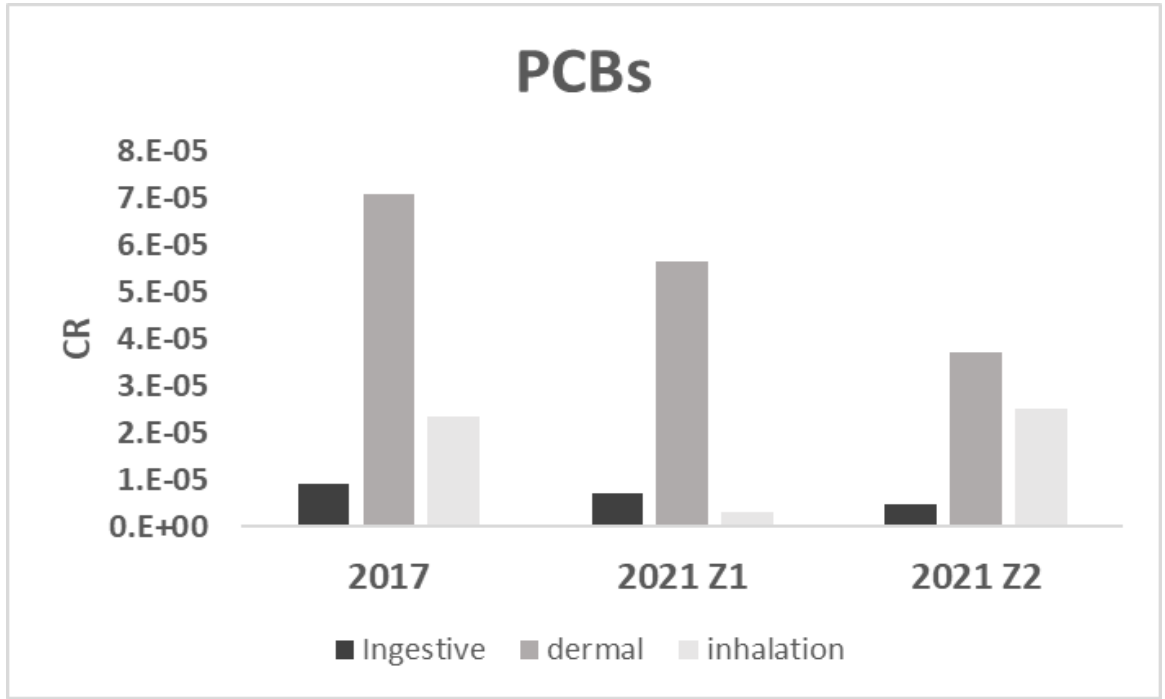
$$HQ_{dermal} = \left[\frac{Ci \times SA \times AF \times ABS \times EF \times ED \times CF}{BW \times AT} \right] / RfD \times GIABS$$

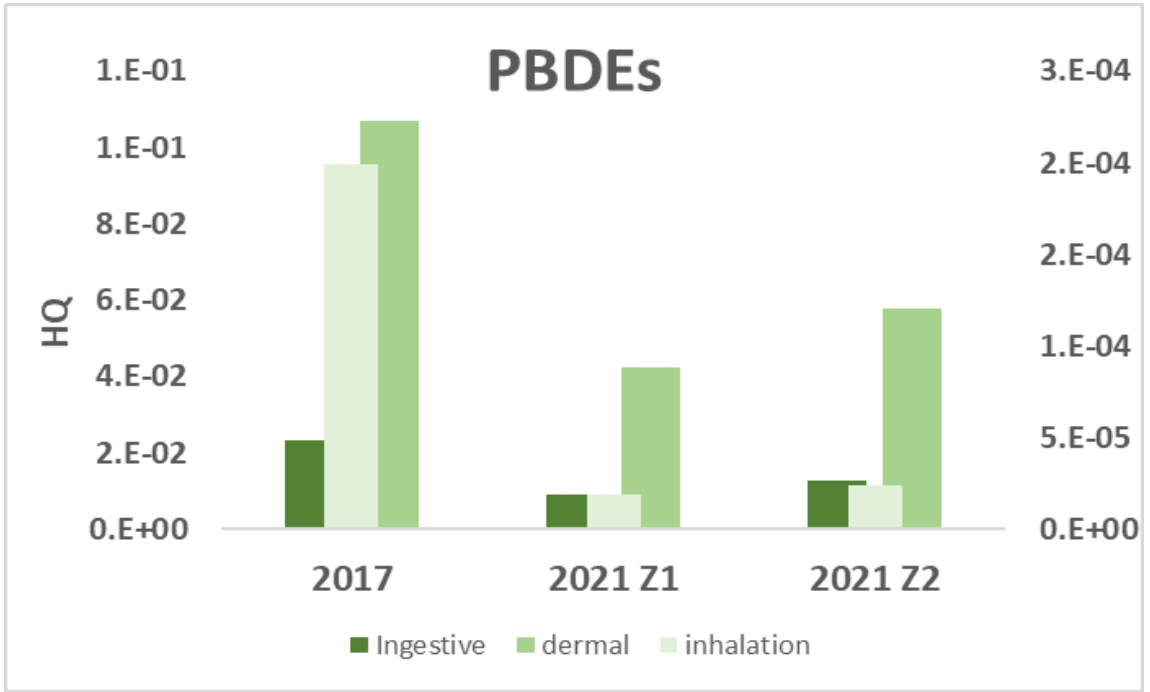
$$TCR = \sum CR_{inhalation} + CR_{ingestion} + CR_{dermal\ contact}$$

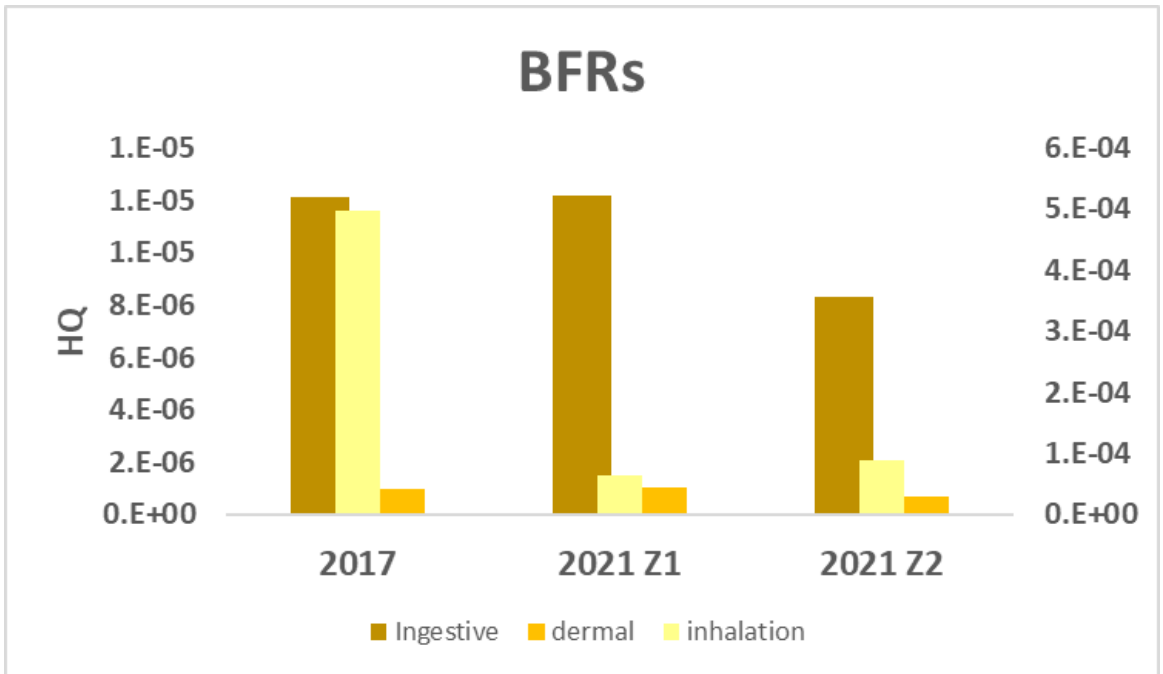
$$THQ = \sum HQ_{inhalation} + HQ_{ingestion} + HQ_{dermal\ contact}$$

Ci	Ci is the contaminant concentration for each compound in PM (µg/m^3) and in settled dust (µg/g),
IngR	Ingestion rate (mg/day)
EF	Exposure frequency (days/year)
ED	Exposure duration (years)
BW	Average body weight (kg)
AT	Averaging time (days or hours*)
CF	Conversion factor (kg/mg)
SFO	Oral slope factor (mg/kg/day)$^{-1}$
SA	Surface area of the skin that contacts soil (cm^2/day)
AF	Skin adherence factor for soil (mg/cm^2)
ABS	Dermal absorption factor (dimensionless)
GIABS	Gastrointestinal absorption factor (dimensionless)
ET	Daily exposure time (8 h/d)
IUR	Inhalation unit risk (mg/m^3)$^{-1}$
RfC	Reference dose for inhalation (mg/m^3)
RfD	Reference dose for ingestion/dermal contact

→PRECAUTIONARY APPROACH


PCBs
CR
8.E-05
7.E-05
6.E-05
5.E-05
4.E-05
3.E-05
2.E-05
1.E-05
0.E+00
2017
2021 Z1
2021 Z2
Ingestive
dermal
inhalation


PBDEs
HQ
1.E-01
1.E-01
8.E-02
6.E-02
4.E-02
2.E-02
0.E+00
3.E-04
2.E-04
2.E-04
1.E-04
5.E-05
0.E+00
2017
2021 Z1
2021 Z2
Ingestive
dermal
inhalation


BFRs
HQ
1.E-05
1.E-05
1.E-05
8.E-06
6.E-06
4.E-06
2.E-06
0.E+00
6.E-04
5.E-04
4.E-04
3.E-04
2.E-04
1.E-04
0.E+00
2017
2021 Z1
2021 Z2
Ingestive
dermal
inhalation

Conclusion

	2017	2021-Z1	2021-Z2	USEPA Recommended Values
TCR	1.03E-04	6.67E-05	6.68E-05	CR < 1 × 10−6 acceptable risk CR< 1 × 10−4 tolerable risk
THQ	1.31E-01	5.18E-02	7.09E-02	HQ <1 no appreciable risk HQ>1 appreciable risk

- ✓ In 2017, TCR data exceeded the tolerable values set by USEPA, whereas THQ results were lower than acceptable risk limits. In 2021, both TCR and THQ are lower than recommended values and about 60% below those found in 2017.

- ✓ Therefore, the plant modifications seem to have resulted in a risk reduction for the workers involved in the treatment of e-waste.